LANDSAT DATA CONTINUITY MISSION (LDCM)

OPERATIONS CONCEPT

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LDCM Operations Concept
Signature Page

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LDCM Operations Concept
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1 Introduction

The Landsat Data Continuity Mission (LDCM) is a joint mission being formulated, implemented, and operated by the National Aeronautics and Space Administration (NASA) and the Department of Interior (DOI) United States Geological Survey (USGS). The LDCM is a remote sensing satellite mission providing coverage of the Earth's land surfaces. This mission continues the 33+ years of global data collection and distribution provided by the Landsat series of satellites.

1.1 Purpose

The primary purpose of the LDCM Operations Concept (OpsCon) document is to provide a description of the planned functions and operations of the LDCM System comprised of space and ground assets. The OpsCon is not a requirements document and does not contain LDCM requirements. Rather, the OpsCon presents a functional view of the LDCM system and operations based on high level program guidance. It represents the operational approaches used to develop and set context for mission and segment requirements. Functions and scenarios described in this OpsCon are not intended to imply design or implementation approaches for the specific elements comprising the LDCM System.

1.2 Scope

The scope of the OpsCon includes all functions associated with the LDCM System as well as those external entities that interact with the LDCM System. Thus, the OpsCon encompasses the collection of image data by the observatory, transmission of data to the ground, and processing, archival, and distribution of the data for the Landsat data user community.

1.3 Background

The Landsat Data Continuity Mission (LDCM) is a component of the Landsat Program conducted jointly by the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS) of the Department of Interior (DOI). The goal of the LDCM is to continue the collection, archival, and distribution of multi-spectral imagery affording global, synoptic, and repetitive coverage of the Earth's land surfaces at a scale where natural and human-induced changes can be detected, differentiated, characterized, and monitored over time. The LDCM goal is in keeping with the Landsat programmatic goals stated in the United States Code (USC) Title 15, Chapter 82 "Land Remote Sensing Policy" (derived from the Land Remote Sensing Policy Act of 1992). This policy requires that the Landsat Program provide data into the future that is sufficiently consistent with previous Landsat data to allow the detection and quantitative characterization of changes in or on the land surface of the globe.

The LDCM was conceived as a follow-on mission to the highly successful Landsat series of missions that have provided satellite coverage of the Earth's continental surfaces since 1972. The data from these missions constitute the longest continuous record of the Earth's surface as seen from space.

The LDCM is intended to ensure that Landsat-like data will be provided to the USGS National Satellite Land Remote Sensing Data Archive (NSLRSDA) for at least 5 years.

1.4 LDCM Mission Objectives

The major mission objectives are as follows:

- Collect and archive medium resolution (*circa* 30 m spatial resolution) multi-spectral image data affording seasonal coverage of the global land mass for a period of no less than five years.
- Ensure that LDCM data are sufficiently consistent with data from the earlier Landsat missions, in terms of acquisition geometry, calibration, coverage characteristics, spectral characteristics, output product quality, and data availability to permit studies of land cover and land use change over multi-decadal periods.
- Distribute LDCM data products to the general public on a nondiscriminatory basis and at a price no greater than the incremental cost of fulfilling a user request.

1.5 Roles and Responsibilities

NASA and USGS, as Landsat Program Management, will share the overall responsibility of fulfilling the LDCM mission objectives and all subsequent requirements. The roles and responsibilities related to this OpsCon are as follows:

NASA will

- Acquire and manage the development of the LDCM space segment and mission operations capabilities
- Acquire and manage the LDCM launch services;
- Manage the LDCM observatory early on-orbit operations from launch through on-orbit acceptance; and
- Transition LDCM mission operations capabilities and observatory operational and maintenance responsibility to USGS, following on-orbit acceptance.

USGS will:

- Manage the development and operation of the LDCM data processing, archive, and distribution system(s);
- Manage the development and operations of the LDCM ground network;
- Manage the development and operations of the LDCM data collection scheduling capability

- Operate the LDCM observatory following on-orbit acceptance; and throughout the life of the mission.

1.6 Document Organization

Section 1 of the document provides the introduction to this document. Section 2 provides a high level overview of the LDCM System. Section 3 describes the LDCM operational concept as a series of segments and functions, sufficient to understand the system capabilities and interfaces. Section 4 presents an overview of the logistics support and sustaining engineering that will be provided to the LDCM. Section 5 describes the operational phases of the mission and illustrates LDCM operational scenarios for selected sequences of events during the mission life.

1.7 Applicable Documents

LDCM Lexicon

2 System Concept

The LDCM System includes all components and capabilities, both space and ground based, that are under the developmental and operational responsibility of the LDCM NASA-USGS interagency team. For mission definition and formulation purposes, the LDCM System is defined at the highest level in terms of four segments - the Space Segment, Flight Operations Segment, Data Processing and Archive Segment, and the Launch Segment. See Figure 2-1.a. It should be noted that the specific functions within these segments may change during the implementation phase of the LDCM.

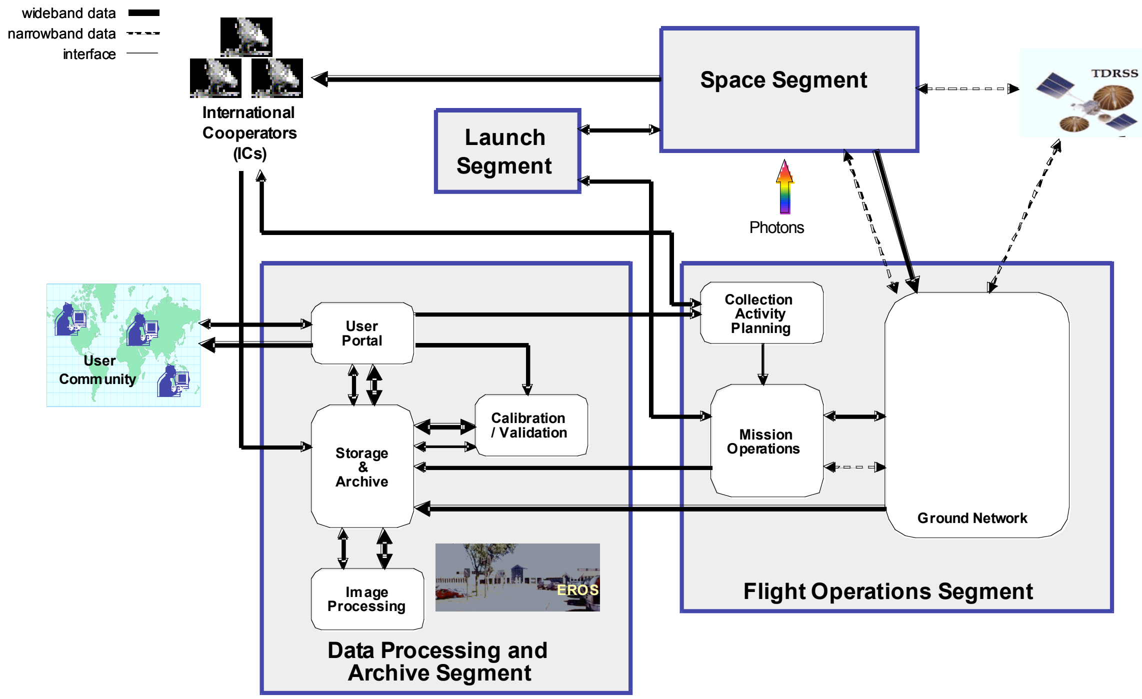

Figure 2-1: LDCM System and Operations Concept

2.1 Space Segment

The Space Segment (SS) consists of the observatory and pre-launch ground support equipment (GSE). The observatory is comprised of the imaging instrument(s) and the spacecraft platform(s). The observatory will operate in a 705 Km orbit with a 16-day repeat cycle and a 10:00 a.m. (+/- 15 minutes) mean local equatorial crossing time. Instrument and ancillary data will be collected, stored onboard and subsequently downlinked to ground stations within the LDCM ground network. Additionally, a real-time downlink capability will transmit instrument and ancillary data to the LDCM ground network and International Cooperators (ICs) equipped to receive these data. The observatory will also receive and execute commands and transmit telemetry. The GSE provides the functionality to perform ground-based integration and testing of the observatory prior to launch.

2.2 Flight Operations Segment

The Flight Operations Segment (FOS) includes Collection Activity Planning functions, the Mission Operations Element, and the LDCM Ground Network. The Collection Activity Planning (CAP) function defines the set of images to be collected by the observatory on a daily basis. The Mission Operations Element (MOE) plans and schedules observatory activities, commands and controls the observatory, and monitors the health and status of the observatory and ground operating systems. The MOE hardware and software systems reside in the LDCM Mission Operations Center (MOC). The LDCM Ground Network (LGN) includes the ground stations that will communicate with the observatory for commanding and monitoring, and will receive image data from the observatory. The LGN will also route data between elements of the FOS and the Data Processing and Archive Segment.

2.3 Data Processing and Archive Segment

The Data Processing and Archive Segment (DPAS) ingests, processes, and archives all LDCM image data. Storage and Archive functions perform ingest and long-term archival. The Image Processing function processes all data received to assess quality and performance, while Image Assessment functions perform characterization and calibration updates. A capability to receive and fulfill user requests for LDCM image collections and data products is provided by the DPAS User Portal function. The DPAS will be located at the USGS Center fro Earth Resources Observation and Science (EROS) in Sioux Falls, SD.

2.4 Launch Segment

The Launch Segment (LS) provides those assets and services associated with the launch vehicle (LV) and the payload integration. Included, along with the launch vehicle, are all launch vehicle ground support equipment (including hardware and software), property, and facilities to integrate the spacecraft to the LV, verify their integration, and conduct pre-launch testing with ground-based functions.

2.5 LDCM System Interfaces

There are certain external entities that provide information to, or receive information from the LDCM System.

<u>TDRSS</u>
NASA's Tracking and Data Relay Satellite System (TDRSS) network will provide S-band communications capabilities for LDCM. TDRSS is a communication signal relay system that provides continuous tracking and bi-directional data transmission services between low earth orbiting spacecraft and ground receiving stations, using satellite to satellite communications links to allow communications even when the target satellite is not in view of a ground station. LDCM will utilize TDRSS during launch and early orbit operations, at a minimum, for telemetry, tracking, and control.

<u>External Data Sources</u>
LDCM will utilize certain external data as input to the Flight Operations Segment and the Data Processing and Archive Segment. These data will include auxiliary data such as government-provided ground control data and digital elevation models for terrain correction or lunar radiance data to support instrument calibration. External data will also include cloud prediction information used in

data collection scheduling, or other data that are used to operate the mission or produce LDCM data products.

NORAD
The Air Force Cheyenne Mountain staff presently support NASA TDRSS and Earth science missions by performing routine conjunction assessment. This facility sends a message to the LDCM FOS whenever there is a possible conjunction with a safety buffer around LDCM. The conjunction analysis is based upon LDCM state vector information, sent to the ESMO ESC (refer to description below). There are three levels of warning, with three associated volumes used for the conjunction analysis.

Earth Science Mission Operations (ESMO)
The ESMO office at NASA GSFC is responsible for the operation of several NASA Earth science missions. The LDCM orbit will allow LDCM to fly as part of a morning constellation that includes several ESMO missions, if they are still operational. (This constellation presently consists of Landsat 7, Terra, EO-1 and SAC-C.) Any required orbit or maneuver coordination to maintain this constellation is performed through human interaction with the ESMO staff and the potential exchange of state vectors corresponding to satellite orbits.

2.6 Primary Internal & External Users

Users
Users encompass all those members of the general public that use Landsat data for purposes as diverse as scientific research and operational resource management. Users interface to the Data Processing and Archive Segment to search for, browse, order, and receive LDCM data products, and to request image collections

International Cooperators
The USGS maintains agreements with several foreign entities (typically, governmental) referred to as the LDCM International Cooperators (ICs). The ICs are a special set of Users that have the ability to receive LDCM data from the observatory real-time downlink stream. Real-time instrument and ancillary data (including spacecraft, calibration data, etc.) necessary for processing are contained in the real-time stream and are received by IC ground stations.

Prime Mission Contractor (PMC)
The LDCM Prime Mission Contractor (PMC) is the contractor who will provide the LDCM Space Segment and Mission Operations Element under contract to NASA. The PMC will perform LDCM mission operations from launch through on-orbit acceptance of the observatory and mission operations systems by NASA. Following on-orbit acceptance and the transition to USGS, the PMC will provide

sustaining engineering support to USGS. The PMC may include sub-contractors, but for the purposes of this document, the entire team is referred to as the PMC.

Flight Operations Team (FOT)
The LDCM Flight Operations Team (FOT) is the team of mission operations personnel managed by the USGS. The FOT will assume full operations of the observatory following on-orbit acceptance.

Data Collection Planner
The USGS Data Collection Planner (DCP) manages the data collection schedules for LDCM. The DCP operates the collection activity planning function within the Flight Operations Segment. The DCP may be an individual or a team of staff who share the DCP responsibilities.

Landsat Science Team
The USGS convenes a Landsat Science Team composed of competitively selected investigators. The Team will conduct research on issues critical to the success of the LDCM, including data acquisition, product access and format, practical applications, and science opportunities for new- and past-generation Landsat data. The Team will offer research and science support to the USGS on topics that will affect the overall success of the LDCM mission. The Science Team will also include NASA science representation.

Independent Cal/Val Team
The Independent Calibration/Validation (Cal/Val) team consists of discipline scientists and engineers who perform calibration of the LDCM instrument(s) and data. The Independent Cal/Val Team is geographically dispersed and includes members from both NASA and USGS. While the team will advise the PMC in instrument calibration, they will remain independent from the PMC in their calibration assessments through the life of the mission. NASA leads this team during observatory development through on-orbit acceptance. Following on-orbit acceptance, this team is led by USGS. The Independent Cal/Val Team works with members of the LDCM Science Team on various calibration and validation issues and special collections of LDCM data.

3 Functional View of Operational Concept

The LDCM operational concept is presented in this section as a set of functions required to operate the LDCM. The allocation of functions to specific segments and any grouping of functions within segments are based on experience gained from developing similar systems. However, this allocation is not meant to constrain the LDCM system architecture that will be defined later in the development cycle. Therefore, while the objective of the OpsCon is to capture all necessary functionality of the LDCM operations, some functions may ultimately be allocated to different segments at a later time.

3.1 Space Segment

The LDCM observatory and associated GSE make up the Space Segment. The LDCM observatory consists of the spacecraft and instrument(s).

3.1.1 Observatory

Planned for a 5 year minimum mission life, the LDCM observatory will operate in 705 Km sun-synchronous orbit. The observatory will have a 16-day ground track repeat cycle and a 10:00 a.m. (+/- 15 minutes) mean local equatorial crossing time. This will allow image collections to be referenced to the second Worldwide Reference System (WRS-2).

The LDCM observatory will perform the standard functions of image data collection, communications, command and data handling, and attitude and orbit control. The observatory will receive S-band communications from LDCM ground stations and TDRSS. Commands and spacecraft software updates received via the S-band communications stream will be managed on-board, and forwarded to the respective observatory sub-systems for execution. The observatory will nominally receive daily command loads encompassing 72 hours of observatory activity. If another command load has not been received at the end of the 72 hour period, the observatory will automatically enter a safe operational state. The observatory will record health and safety telemetry at all times. During contacts with a ground network station, the real time telemetry data will be downlinked. Stored telemetry data will also be downlinked over the wideband link.

The observatory will have the ability to determine ephemeris and manage spacecraft timing. Navigation and attitude sensor data (raw and processed) will be stored and transmitted as part of the observatory telemetry. The observatory will perform attitude and orbit adjustments as commanded to maintain the WRS-2 and image quality requirements, and to perform required calibration maneuvers. Power and thermal management functions will also be performed on-board.

The observatory will monitor the health and status of each sub-system including the instrument(s). Corresponding telemetry will be generated and stored on-board for future transmission to the LDCM ground stations. Additionally, observatory telemetry will be transmitted in real-time via S-band communications to TDRSS and LDCM ground stations.

If any of a pre-defined list of anomalies occurs, the observatory will have the ability to detect the anomaly and automatically place the observatory in a safe and protected state until the anomaly is resolved.

The LDCM observatory will nominally collect multispectral images of the Earth referenced to WRS-2. Additionally, the observatory will be able to collect image data along a WRS-2 path adjacent to the observatory ground track in lieu of imaging the nadir WRS-2 path. The observatory will collect images of the moon for instrument calibration. The observatory may also perform additional instrument or attitude sensor calibrations using on-board calibration systems or other maneuvers (e.g. gyro calibration maneuver), if necessary.

The LDCM observatory will collect image data in the form of image intervals – periods of time (typically, seconds to minutes) in which the observatory is collecting image data of the Earth or calibration targets. The observatory will be capable of collecting 1 or more image intervals per orbit, and the separation between image intervals may be as small as the time required to collect 1 WRS-2 scene. The observatory will collect image data at an expected rate of at least 400 WRS-2 scenes meeting image quality requirements plus required calibration data per 24-hour period.

Earth image data and calibration data may be collected at any point in the orbit, and will be temporarily stored on board the observatory. Image data will be transmitted via a wideband communications stream to LDCM ground stations, and will be real-time downlinked to both the International Cooperators (ICs) and LDCM ground stations. Priority image data collections will be downlinked in advance of non-priority collections to the first available LDCM ground station or to an IC. The wideband data stream will also contain ancillary data, including instrument and select spacecraft telemetry, calibration data, and other data necessary for image processing. The observatory will be capable of transmitting the equivalent of at least 400 WRS-2 scenes meeting image quality requirements and associated calibration data per 24-hour period.

The observatory will be capable of simultaneously collecting, storing, and transmitting (both in real-time and playback) telemetry and image data. The observatory will also be capable of re-transmitting telemetry and image data if the original transmission was not properly received.

3.1.2 Ground Support Equipment

Both electrical and mechanical Ground Support Equipment (GSE) interfaces to the LDCM observatory, and are essential to successful observatory integration and verification. The electrical GSE originates test commands internally and receives responses from the observatory during observatory level integration and test. The mechanical GSE is used during final assembly of the observatory for the installation and testing of any mechanical components.

A subset of the integration and test GSE will travel to the launch site to support observatory final preparations for launch. The electrical GSE at the launch site will be used in the payload process for launch as well as during the launch count down to place LDCM observatory in its final launch configuration.

3.2 Flight Operations Segment

The LDCM Flight Operations Segment (FOS) includes all of the ground-based assets needed to operate the LDCM observatory. This segment is also responsible for maintaining observatory health and safety and on-orbit sustaining engineering. The primary capabilities of the FOS are Collection Activity Planning; Mission Operations; and the LDCM Ground Network.

3.2.1 Collection Activity Planning

The FOS Collection Activity Planning (CAP) functions build and manage a collection activity request for the LDCM instrument(s). The collection activity plan includes:

- Imaging requests to support the LDCM Global Mission Acquisition Plan (GMAP), which provides requirements for Earth land imagery collections based on seasonality, cloud climatology, and other factors.
- International Cooperator imaging requests
- Non-routine instrument calibration activities, such as lunar calibrations.
- Special imaging requests

Daily cloud cover predictions from the National Center for Environmental Prediction (NCEP) are input to the CAP functions to identify the best opportunities to collect cloud-free images. Factoring in cloud cover, the CAP de-conflicts the requests and develops the collection activity request. The collection activity request is optimized to meet a maximum number of requests while fulfilling the GMAP requirements. The criteria for prioritizing collection requests will be defined and documented within CAP operating procedures. CAP will generate a collection activity request every 24 (TBR1) hours, and each request will encompass 72 (TBR2) hours of activities.

Special imaging requests, such as for natural disasters or to support unique science research campaigns, are forwarded to the LDCM DCP – a USGS team member(s) responsible for coordinating and approving special requests. The DCP interacts with the CAP functions of the FOS. The Data Collection Planner evaluates the special requests using the prioritization criteria and determines whether or not they will be scheduled for collection. Certain special requests, called priority requests, are those time-critical image collections of national or international interest (e.g. natural disasters). Priority requests are flagged by the DCP to be expedited through the entire image collection and production process.

3.2.2 Mission Operations

The FOS Mission Operations Element includes four primary functions; Mission Planning and Scheduling; Command and Control; Flight Dynamics; and Long-Term Trending. The capabilities to perform these functions will physically reside in the Mission Operations Center (MOC).

A limited number of MOE functions will be available through remote access. Remote access to selected MOE functions will allow FOT to perform certain operations functions without being present in the MOC. Observatory commanding will *not* be performed via remote access.

3.2.2.1 Mission Planning and Scheduling

Mission Planning and Scheduling (MPS) functions will plan/coordinate and schedule observatory and ground station (TBR3) activities. A key input to this function is the collection activity plan developed by the CAP function. In addition to the received image collection activity plan, MPS will plan and schedule

- Observatory activities such as orbit adjustments, routine calibrations, maneuvers, and ground station contacts.
- Ground station contacts including those to the LDCM Ground Network, ICs, and those performed through TDRSS (TBR4).
- Ground network activities required to transfer data between ground stations and the MOE or DPAS.

In order to develop activity plans and schedules, the MOE will also perform activity management functions such as activity prioritization, activity resource allocation, and allocation of operational constraints. Additional resource management will also be performed by the MOE including tracking of ground systems hardware and software downtimes and preventive maintenance.

Incorporating the collection activity request, the MPS functions will plan and schedule these activities, perform any schedule de-confliction, and generate the observatory activity schedule. The MPS will generate an activity schedule every 24 (TBR5) hours, and each schedule will encompass 72 (TBR6) hours of observatory operations.

3.2.2.2 Command and Control

The Command and Control Function builds command loads for transmission to the observatory. Command loads are built to implement observatory activity schedules and flight software updates. Observatory activity schedules will be received from the MPS function, while flight software updates will be received from the LDCM Prime Mission Contractor. Commands are formulated into encrypted RT CCSDS commands and routed to the LDCM Ground Network or through TDRSS for transmission to the observatory. Commands will only be generated from a single MOC terminal at any given time. I.e. only one FOT member resident in the MOC will have the ability to command the observatory at any given time.

The Command and Control function monitors the LDCM observatory beginning with the receipt of real-time (RT) and stored downlinks from the LDCM Ground Network or through TDRSS. Spacecraft housekeeping telemetry is monitored and limit checked. Out of limit values will trigger visual indicators, alarms, or other notification (e.g. paging) of the Flight Operations Team (FOT).

New commands are developed and tested off-line using an observatory simulator. This simulator receives and executes test commands, simulates resulting telemetry, and sends it back to the MOE for analysis by FOT personnel. All new commands will be fully tested prior to transmission to the observatory. The observatory simulator will also be used for FOT training and anomaly resolution.

3.2.2.3 Flight Dynamics

Flight Dynamics functions include

- Orbit analysis and propagation
- Maneuver planning in order to maintain the proper LDCM orbit
- Calibration of any observatory on-board sensors
- Determination of ground station masks and available LGN ground station contact times
- Determination of potential TDRSS contact times
- Definitive ephemeris generation

3.2.2.4 Trending and Analysis

All housekeeping telemetry for the mission is stored on line in order to perform Trending and Analysis functions. A suite of analysis tools is provided for the FOT and engineers to perform long-term trending, analysis, anomaly investigation, etc. With these functions, FOT personnel can generate automated and user-definable statistics, plots, and reports.

3.2.2.5 Autonomy

The MOE will have the capability to support non-commanding operations autonomously. When the observatory is operating based on a command load, the MOE will be able to support mission operations without staffing for periods of time. Unstaffed operations include contacts with ground stations and real-time monitoring of the S-band telemetry data within the command and control function. Any problems detected will cause the MOE to autonomously activate a notification and call-in system for the FOT. This autonomous operations capability would not be implemented early in the mission, during maneuvers, or other times of increased risk.

3.2.2.6 Backup MOE and Backup MOC

The FOS will include a backup MOE (bMOE). The bMOE will have all the capabilities of the MOE, but with less redundancy. The bMOE will be located in a backup MOC facility, at a geographically separated location that allows it to serve as a backup in the event of a critical failure, malicious attack, or natural disaster at the primary MOC facility.

3.2.3 LDCM Ground Network

The FOS includes a ground-based capability for communicating with the observatory, called the LDCM Ground Network. The LDCM Ground Network is comprised of 2 (TBD3) nodes located at Sioux Falls, SD and Fairbanks, Alaska (TBD4). These stations will be fully dedicated to LDCM. A third station at TBD location may be used as a backup.

Each node in the LDCM Ground Network includes a ground station that will be capable of receiving LDCM wideband data. Additionally, each station provides complete S-band uplink and downlink capabilities. These enable the Command and Control function to interface to the observatory.

The LDCM Ground Network includes a data routing capability. This allows the transfer of data and commands/telemetry between the nodes, the Command and Control function, and TDRSS in a secure manner. If data is not successfully received by a node, the LDCM Ground Network will be capable of re-transmitting data between nodes.

3.2.3.1 Tracking Data Relay Satellite System Interface

The LDCM Ground Network will interface to the NASA Tracking Data Relay Satellite System (TDRSS). This interface will be used for S-band communications during the launch and early orbit of the LDCM observatory, and potentially for critical maneuvers or anomaly resolution. The LDCM Ground Network will interface to TDRSS through the TDRSS White Sands Complex (WSC) in Las Cruces, NM. The WSC will perform S-band communications directly with the TDRSS satellites. The TDRSS satellite(s) will continually track the LDCM observatory to provide a continuous real-time S-band link. The availability of TDRSS capabilities will be coordinated between the WSC and the Planning and Scheduling function within the Flight Operations Segment.

3.3 Data Processing and Archive Segment

The Data Processing and Archive Segment (DPAS) includes those functions related to ingesting, archiving, calibration, processing, and distribution of LDCM data and data products.

3.3.1 Storage and Archive

The Storage and Archive Function receives all LDCM data from the Flight Operations Segment for archival. LDCM wideband data are made available to the image processing function and pre-processed into a format for archival (refer to section 3.3.2).

The Storage and Archive Function archives all LDCM data. The LDCM data includes LDCM image data, telemetry data, ancillary data, and mission related data (e.g. engineering and pre-launch test data, development and engineering documentation from all phases of the program). Ancillary datasets include Digital

Elevation Models (DEMs), water mask datasets, and ground control datasets. The total volume of the data archived is nominally 275 GB per day or 510 TB for a five year mission.

In addition, the Storage and Archive Function:

- Maintains the safety and integrity of all archive media, including the management of an offsite copy of all archived LDCM data.
- Maintains a mission database -- metadata information that describes all LDCM data in the archive. The mission database is used as a data inventory.

3.3.2 Image Processing

The Image Processing function includes all processing functions within the DPAS. This includes processing data for archival and generating data products.

The Image Processing Function generates browse imagery and metadata for all image collections stored in the LDCM archive. Additionally, all instrument data is processed to ascertain quality assessment information. This processing includes verifying any checksum fields, estimating bit error rate, performing limits checking on metadata parameters, etc. A quality assessment process also includes a visual inspection step performed by operations staff. Cloud cover scores, and other information are also generated.

The Image Processing function extracts detector-level statistics and related information for use by the calibration and validation function.

The Image Processing function extracts archived data granules, prior to delivery, for other requesting DPAS functions. The extraction activity may include extracting/combining data for a requested time interval, extracting only a certain set of bands, creating a seamless granule, etc. The image processing function generates all the LDCM data products distributed by the DPAS. This includes generation of Level 0 and Level 1 products.

3.3.3 User Portal

The User Portal Function provides the LDCM interface to data users, and manages the generation and completion of orders for LDCM data products. (Note that ICs may access the User Portal to order products as well.) The User Portal includes a discovery capability that allows users to search for LDCM data products, place orders, request LDCM image collections, and supports a bulk order capability.

The User Portal includes financial functions related to billing and accounting and the exchange of funds for data product sales and returns.

The User Portal provides public access to related LDCM information. This includes: Calibration reports; calibration data; documentation; data format descriptions and similar types of information.

3.3.4 Image Assessment

The Image Assessment Function ensures that the LDCM data products meet all the radiometric, geometric and spatial performance requirements. This function uses stored data from the DPAS Storage and Archive Function to generate calibration parameters. The calibration parameters are used by the Image Processing Function to generate data products which meet performance requirements.

The Image Assessment Function provides the capability to characterize LDCM products for radiometric, spatial and geometric performance. This refers to both Level 0 LDCM data and to all the Level 1 products generated by the Image Processing Function. This function also performs analysis of LDCM archive data (both sensor data and telemetry) to extract various calibration-related parameters and data. (Note that the latter function executes within Image Processing for performance reasons.)

The Image Assessment Function has a critical human-in-the-loop element. The LDCM Independent Calibration and Validation (Cal/Val) Team oversees all calibration performed by this function. The Independent Cal/Val Team members perform analysis of calibration data and collectively decide on updates to LDCM calibration parameters, and on the need for observatory calibration maneuvers and calibration data collections.

3.4 Launch Segment

The Launch Segment consists of the Launch Vehicle (LV) and the associated facilities, equipment and services needed to place the LDCM observatory into orbit.

The LDCM will be launched from the Western Range at the Vandenberg Air Force Base (VAFB) located near Lompoc, California. The LDCM space segment will be transported to VAFB to prepare for launch. A payload processing facility (PPF) will be assigned at VAFB to support the final observatory integration and test activities required before launch.

3.4.1 Launch Vehicle

The LDCM launch vehicle and associated launch services will be procured by NASA's Kennedy Space Center (KSC). The LV will be a NASA Medium-class (e.g. Delta II) Expendable Launch Vehicle. The LV will be delivered to the launch site and VAFB. The LDCM observatory will be mated to the LV at the launch site.

3.4.2 Launch Vehicle Ground Support Equipment (LV-GSE)

The launch vehicle ground support equipment (LV-GSE) are those mechanical, electrical, communications, propulsion, and monitoring equipment needed to provide launch base services for the LDCM launch. The majority of the LV-GSE is internally unique to the LV and has few interfaces to the LDCM. There are several items in the LV-GSE that affect LDCM operations. These include:

- Blockhouse console for pre-launch power and commands to the observatory, and hard line monitors and telemetry from the observatory via the LV umbilical
- Communications interface equipment to allow command and telemetry from the observatory electrical GSE to interface with the observatory while it is mated to the LV
- Observatory handling equipment for mating the observatory to the LV, for installation of the fairing, and ensuring a temperature and humidity controlled environment

4 Logistics Support and Sustaining Engineering

The following logistical and sustaining engineering support will be provided as part of the LDCM operations.

4.1 Logistics Support

4.1.1 Facilities

The Facilities Logistics functions provide LDCM physical infrastructure. The physical infrastructure includes everything needed to operate the Flight Operations and Data Processing and Archive Segments except for the information technology infrastructure and the ground station antennas. A non-inclusive list of items provided as part of the physical infrastructure is:

- Power, including backup power
- Heat and air conditioning
- Environmental services
- Buildings, including operating buildings, warehouses, and storage areas
- Facility maintenance
- Roads
- Vehicles
- Construction
- Foundations for antenna

The LDCM will be responsible for assuring that LDCM infrastructure needs are met. It is expected that most ground equipment will be located at a USGS facility, at a facility owned by another organization, or both. In either case, the LDCM will act as a tenant. Thus LDCM facilities logistics is primarily a management role – coordinating with the site facility manager for facilities needs and funding.

4.1.2 Security

Security plans and procedures will be developed for LDCM later in the development life cycle. Security logistics are expected to include

- Secure access to critical operations facilities such as the Mission Operations Center (MOC), backup MOC (bMOC), and ground station facilities as specified in the USGS LDCM System Security Plan.
- Information technology measures to ensure undisrupted operations of LDCM software or network capabilities as specified in NPR 2810.1 and the USGS LDCM System Security Plan.

4.1.3 Training

Details of LDCM operations training will be established later in the LDCM development cycle. FOT training is expected to include:

- Involvement in observatory integration and testing, including training on observatory engineering and operations
- All LDCM routine and contingency operations procedures
- Use of MOE hardware and software systems
- Maintenance of MOE hardware and software systems

The LDCM Flight Operations Team is expected to be knowledgeable on the testing and operations of the LDCM instrument(s) and spacecraft, beginning well in advance of LDCM launch, through integration of the Flight Operations Team with the space segment engineering and test teams. Training of the LDCM Flight Operations Team will ensure that they are well-prepared and ready to safely operate the observatory.

Training will take various forms, depending on the type of training. For example, operators will be trained using equipment that emulate the interfaces and simulates observatory performance with high fidelity. Software and hardware maintenance personnel may receive training from vendors on specific programs or equipment.

4.1.4 Management Support

Management support will provide all management data needed by the LDCM team. Management support logistics functions will include:

- Property management, to be performed in accordance with NASA and USGS policies.
- Configuration management, to be performed in accordance with the LDCM Configuration Management Plan.
- Risk management, to be performed in accordance with the LDCM Risk Management Plan. It is intended that risk management will be done proactively, and that this topic will be included in operator training.
- Safety, to be consistent with NASA and USGS safety plans, guidelines, and procedures.

4.2 Sustaining Engineering

Sustaining engineering support will be provided throughout the life of the LDCM and will support, the Space Segment, Flight Operations Segment, and Data Processing and Archive Segment. All sustaining engineering functions affecting operations will be coordinated with the LDCM FOT to assure that routine support does not interfere with operations.

4.2.1 Role of Prime Mission Contractor

The LDCM Prime Mission Contractor will provide observatory sustaining engineering support during the 5-year mission life. Observatory sustaining engineering will primarily support non-nominal operations such as anomaly resolution and flight software updates. The Flight Operations Team will coordinate with the Prime Mission Contractor for access to and exchange of data and information necessary to perform observatory sustaining engineering, and will coordinate observatory sustaining engineering activities to avoid disruptions to routine flight operations.

Observatory sustaining engineering will include review of data, technical/engineering analyses, and review of changes to documentation. Sustaining engineering will also include investigation of on-orbit observatory anomalies and recommendations for resolution.

Observatory sustaining engineering will also include flight software updates and maintenance. The Prime Mission Contactor will maintain the flight software development environment and will provide flight software updates to the MOE for uplinking to the observatory. Standard procedures for flight software updates will be developed and tested prior to launch. All updates will be tested on a non-interference basis.

The Prime Mission Contractor will also provide support for MOE maintenance, including investigation of MOE system anomalies and recommendations for resolution.

4.2.2 Ground Hardware

Ground hardware sustaining engineering will encompass the installing, monitoring, testing and maintaining all hardware within the Flight Operations and Data Processing and Archive Segments. FOS and DPAS hardware includes, but is not limited to computer systems, ground station antennas, IT equipment; and communications equipment. It is expected that the FOS and DPAS architectures will be modular in nature so that future upgrades are easy to perform. The precise way that ground hardware sustaining engineering will be done will be further defined in the FOS and DPAS operations concept documents. The maintenance of equipment and implementation of new equipment will be conducted with emphasis on transparency to the FOS and DPAS operations. The maintenance and installation process will be compatible with the property management policies referenced in Section 4.1.4.

4.2.3 Ground Software

Ground software sustaining engineering includes installing, monitoring and maintaining all LDCM software, databases and processors within the FOS and DPAS, including IT administration software, operational and ground software. Ground software sustaining engineering does not including observatory flight software.

The ground software sustaining engineering activity is generally concentrated on monitoring and maintaining operations; however, software may also be developed to make the operations more efficient. It is expected that the software provided will be modular and interoperable so that upgrades are easily and cost-effectively performed. All operational software must follow standard procedures and rigorous testing. Defined software processes will be used and data on how well these processes perform will be collected and used in improvement efforts.

Potential software upgrades and new programs will be evaluated. When the decision is made to use either new or an upgraded version of software, the software will be tested prior to installation. No operational software will be introduced to the LDCM operational system until after it has been thoroughly tested using operational data in a high fidelity simulation environment. Testing and installation of new or modified software will be performed to ensure transparency and non-interference to operations.

5 Operational Phases and Scenarios

LDCM operations are described within the context of five phases:

- Pre-Launch
- Launch and Early Orbit
- Commissioning
- Operations
- Decommissioning

5.1 Pre-Launch

The Pre-Launch phase runs throughout the course of instrument(s), observatory, and ground-based system development, testing, and integration through the final phase of launch readiness.

In the Pre-launch phase, the Prime Mission Contractor (PMC) will design, develop, integrate and test the LDCM observatory. These activities will occur at the PMC facilities. The Independent Cal/Val Team will participate in the instrument level testing with the PMC. This will include independent characterization of the radiometric sources used by the PMC to calibrate the space segment instruments. The Independent Cal/Val Team will also independently analyze selected PMC-collected data. Observatory development progress will be assessed through a comprehensive set of peer and independent reviews.

During these activities, the anticipated roles of the LDCM Flight Operations Team will include observing and/or participating in testing and integration of the instrument(s) and observatory.

In parallel with the design and development of the space segment, the design and development of the FOS and DPAS will take place. Early activities will include requirements decomposition, design of segment components and interfaces, and design of interfaces to the space segment. The FOS and DPAS requirements and designs will be reviewed at the ground System Requirements Review (SRR), Preliminary Design Review (PDR) and Critical Design Review (CDR), and also at mission-level reviews.

Prior to significant integration and test of the observatory and ground systems, a Mission Operations Review (MOR) will take place. The purpose of the MOR is to demonstrate that all aspects of flight and ground operations are incorporated into the plans and schedules necessary to support integration at the PMC facility and the launch site, as well as launch and early orbit, routine mission, and end-of-life operations. Flight and ground system operational interfaces and operations plans will be reviewed during the MOR.

FOS testing and training will take place during the Pre-launch phase to assess the performance of the functions and components within the FOS. The PMC will perform integration and testing of the Mission Operations Element (MOE), and will deliver and integrate it within the MOC. The PMC will provide training to the FOT on the use of the MOE. The FOT and PMC will work together (TBR) to perform integrated FOS testing and integrated ground system testing. Key operational aspects of the testing will include testing functions such as command generation and transmission to the LDCM Ground Network and operations of the LDCM ground stations. Interfaces between the observatory, LDCM ground network, the ICs, and TDRSS will also be tested.

The functions and components within the DPAS will also be tested during the Pre-launch phase. PMC-collected data will be used to develop the algorithms and software in the Image Assessment function within the DPAS. Interface tests between the DPAS and FOS will take place. From a mission operations standpoint, the emphasis is on the interface between the DPAS and the LDCM Ground Network, which ensures that the DPAS will be able to receive LDCM wideband data.

A Flight Operations Review (FOR) will occur just prior to the last major interactive test between the flight and ground system elements before shipment of the observatory to the launch site. At the FOR, the results of its mission operations activities will be reviewed to demonstrate compliance with requirements, and that the ability to execute all phases and modes of mission operations has been demonstrated.

LDCM system integration across all segments will take place and will test the end to end interfaces between the observatory, TDRSS, FOS, and DPAS. This end-to-end data flow tests to demonstrate that both wideband and S-band data can be transferred between the observatory and the FOS, and that the DPAS can receive wideband data and make LDCM data products available for users. Operations testing on the integrated system will be performed using the LDCM operations plans and procedures. Results of any mission simulations will be presented along with remaining discrepancies and work to be performed.

An Operations Readiness Review (ORR) will take place to establish that the LDCM system is ready to transition into an operational state. The ORR will examine the results of observatory, FOS, and DPAS tests, analyses, and operational demonstrations.

A NASA Goddard Space Flight Center (GSFC), government-only, Mission Readiness Review (MRR) will also be conducted. The MRR will assess the readiness of GSFC-managed LDCM missions for launch and on-orbit operations, and will provide the documented basis for certifying to NASA Headquarters that the mission is ready for launch.

Following successful integration and testing of the LDCM, the observatory and associated GSE will be prepared for shipping, and then shipped to launch site.

The Pre-Launch phase continues with the arrival of the LDCM observatory at its assigned payload processing facility (PPF) at Vandenberg Air Force Base (VAFB). Any remaining observatory integration and test activities required before mating to the launch vehicle are performed at the PPF. Observatory GSE is typically linked to the MOE in the MOC via data lines, RF links, and any voice and video lines, if required. The FOS MOE can then exchange telemetry and commands with the observatory through the GSE or through an RF link in the PPF while the observatory is in the PPF or at the launch complex.

At the launch site a Flight Readiness Review (FRR) will take place. This review will assess the overall readiness of the total LDCM system to support the objectives of the mission.

Following final preparations in the PPF, the observatory is transported to the launch complex where it is mated to the LV. All ground-based services to the observatory will be provided through the LV-GSE. The LV umbilical will provide the interface between the observatory and the observatory's electrical GSE in the launch site blockhouse. The observatory electrical GSE provides the MOE command and control functions while the observatory is mated to the LV.

While mated to the LV, an observatory "aliveness" test will take place to ensure the observatory is functioning as expected. This will include the exchange of commands and telemetry between the observatory and the MOE located at the MOC. This test would not involve the observatory electrical GSE. The observatory S-band communications will be open air radiated to antenna "hats" temporarily mounted in the observatory. The S-band communications stream will be routed through the launch site RF network for monitoring by the MOE.

Prior to the LDCM launch, launch dress rehearsals will take place to fully train and prepare launch teams and LDCM FOT. Launch and operations procedures will be followed and refined.

Two to three days before the scheduled launch date, a Launch Readiness Review (LRR) will occur. The LRR will ensure that all flight and ground hardware, software, personnel, procedures, and the launch range are ready to support a safe and successful launch.

5.2 Launch and Early Orbit

The Launch and Early Orbit phase begins with the final countdown to launch and runs through the early orbit checkout of the LDCM observatory.

In this phase, the LDCM FOT will conduct operations of the LDCM from the LDCM MOC. Since the PMC is ultimately responsible for observatory operations during this phase, it is expected that the PMC will appropriately train the FOT, and will oversee all operations within the MOC during this phase of the mission.

The LDCM launch countdown will begin when the NASA/KSC, launch service contractor, LDCM Project, and USAF Western Range (WR) launch teams all agree that there are no impediments to launch. At T=0, the LV begins its ascent from the launch facility. During all powered flight portions of the launch and ascent through observatory separation, the LV transmits telemetry to the LV ground tracking stations and/or instrumented aircraft. If the observatory is powered on, observatory S-band telemetry will be real-time transmitted to TDRSS for relay to the LDCM ground network during launch, and/or will be stored and transmitted following spacecraft activation. After achieving the injection orbit, the LV releases the observatory. Following release, the LV will perform a collision avoidance maneuver.

Early orbit begins at spacecraft separation from the LV. At this point the launch service contractor will provide the FOS MOE with a state vector at observatory separation to provide assistance for early tracking coverage.

The spacecraft will perform a pre-programmed activation sequence after separation from the LV to provide power to the observatory and turn on sub-systems. It is anticipated that orbit adjustments will be made during this phase to move the observatory from its initial parking orbit to its nominal orbit. This will include any coordination needed to bring the observatory into the “morning constellation” of Earth observing satellites. These orbit maneuvers may take several days and will require periodic orbit determination using observatory telemetry and flight dynamics analysis. The NASA Goddard Space Flight Center Flight Dynamics Facility personnel will provide support to the LDCM FOT and the PMC during early orbit.

During early-orbit, the proper functionality of observatory command and data handling functions and attitude and orbit determination and control functions will be demonstrated. The observatory will be capable of continually transmitting S-band telemetry to TDRSS for routing to the FOS MOE. Additionally, the observatory will begin transmitting real-time S-band telemetry directly to the LDCM ground stations. Stored telemetry will also be transmitted using the wideband communications stream to the LDCM ground stations.

During early orbit, activation of the LDCM instrument(s) begins. The instrument(s) will be activated based on a series of steps following outgassing, including powering on of instrument electronics, functional checkout of any on-board calibration sources, generation of instrument health and status, and collection of the first image. Image data and ancillary data will be transmitted via wideband communications to the LDCM ground stations.

The FOS MOE will receive telemetry through the LDCM ground network and will begin monitoring spacecraft status and health. Image and ancillary data will also be received by the LDCM ground network and routed to the DPAS.

5.3 Commissioning

During on-orbit commissioning and acceptance, the LDCM observatory will demonstrate that it meets pre-defined performance requirements through successful completion of observatory acceptance testing. The acceptance testing will address a series of performance requirements for the spacecraft such as command and data handling; attitude & orbit determination and control; power/thermal management; S-band transmit/receive; and wideband transmit capabilities.

Similarly, the LDCM instrument(s) will demonstrate that it meets pre-defined performance requirements through successful completion of instrument acceptance tests. The instrument(s) must produce imagery that meets image quality specifications for geometric accuracy, radiometric accuracy, and spatial response. Instrument calibration will be a significant part of commissioning and acceptance, and will include calibration maneuvers and measurements of on-board sources. Based on these initial calibration data, instrument tuning will be performed. Calibration measurements and maneuvers may be performed multiple times in order to achieve image quality requirements. Operational performance requirements will also be verified, including the collection and delivery of 400 scenes/day over a 16-day period (TBR8).

During commissioning the LDCM observatory may seek coincident acquisitions with operational high- and moderate-resolution imaging sensors. These acquisitions will be coordinated with the operators of those systems as needed.

During commissioning, the DPAS will receive LDCM wideband data routed from the ground network. As part of the acceptance testing, instrument data will be processed using the LDCM algorithms provided by the PMC and implemented by USGS within the DPAS. The geometric, radiometric, and spatial response accuracy of the resulting data products will be assessed against the imagery requirements.

At the completion of on-orbit commissioning, an On-orbit Acceptance Review (OAR) will take place. Upon the successful completion of the OAR, the LDCM Project will officially accept delivery of the observatory and MOE.

5.4 Operations

The Operations phase represents the period between observatory commissioning and decommissioning.

The LDCM operations are illustrated by a series of scenarios. These scenarios provide an overview of the major threads through the Operational Concept to describe how major activities are accomplished. The set of scenarios help in understanding how the LDCM system behaves, and serves as a tool to aid in verifying the completeness of the Operations Concept. The scenarios do not portray every possible situation that may be encountered during operations but serve as a basis for further operations planning.

Each scenario includes a brief description, a list of assumptions, a data flow figure, and a table that describes the key functions and data flows. The figure below illustrates the graphical convention used for these scenarios. In this example, a function happens at step 1 and data flows to step 2. A function occurs at step 2, and then there are two flows shown. In this example, the primary flow is through steps 3, 4 and then 5. This flow always occurs as these steps are numbered sequentially and shown in the same style. There is an optional, alternate flow represented as steps A1, A2 and A3 in the example.

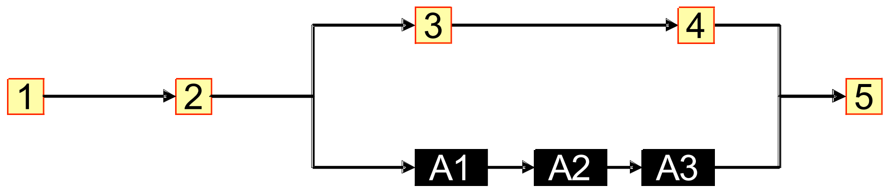

Figure 5-1. Scenario Style Example

5.4.1 Daily Activity Scheduling Mission Scenario (LDCM-01)

5.4.1.1 Description

This scenario illustrates the daily activity scheduling of LDCM image data and providing command loads to the LDCM space segment. This scenario begins with acquisition requests and ends with upload of a command sequence to the spacecraft.

5.4.1.2 Assumptions

- All segments are functioning nominally.

5.4.1.3 Walkthrough

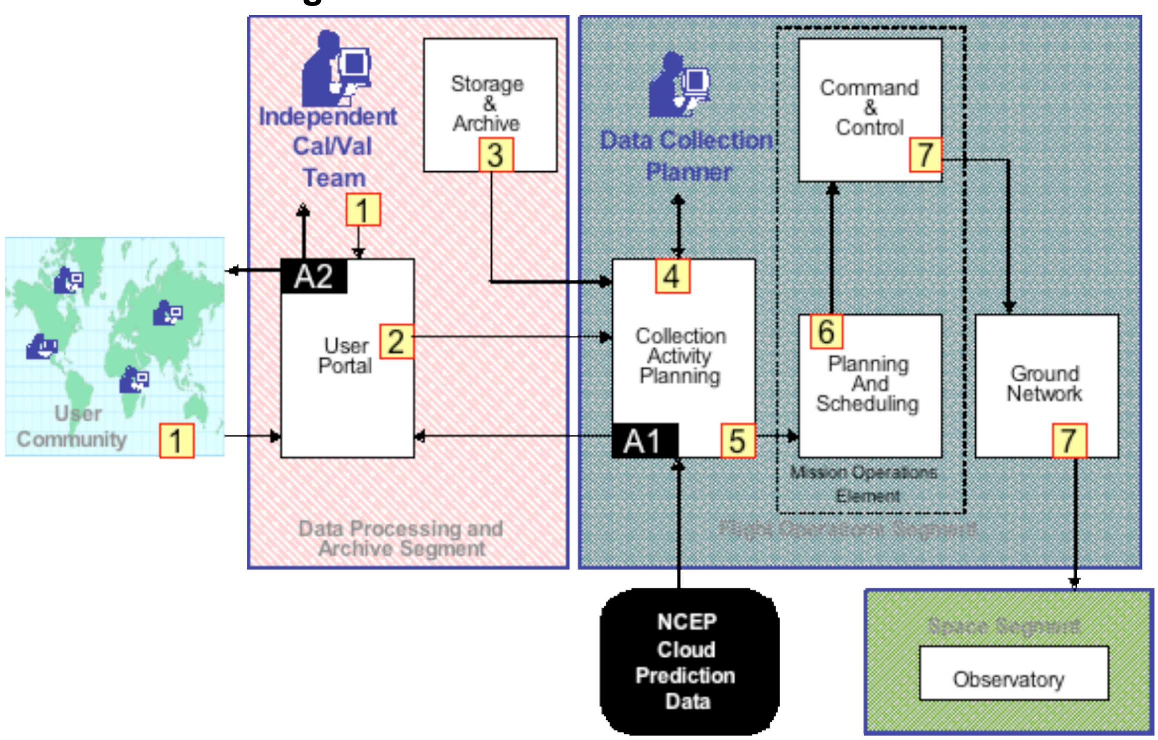

Figure 5-2. Daily Activity Scheduling Mission Scenario (LDCM-01)

Step	Description

Step	Description
1	The User Community generates and submits special image requests that are not in the daily activity or acquisition schedule. The LDCM Independent Cal/Val Team also generates and submits image requests to support instrument calibration. The User Community and Independent Cal/Val Team interface with the DPAS User Portal function to submit requests. Note that all these inputs are optional, as the acquisition schedules will largely be automatically generated.
2	The DPAS forwards the image requests to the FOS for consideration. This step is also optional, since user image requests will not always be made.
3	The DPAS storage and archive function makes the entire inventory of LDCM data in the archive available to the planning & scheduling function. This information includes the cloud cover percentages for all data in the archive.
4	As part of the Planning and Scheduling function, all special image requests are evaluated by the Data Collection Planner for acceptance or rejection, guided by established policy. The accepted requests and GMAP are combined based on predicted cloud cover probabilities, existing archive quality and extent, and observatory or ground system constraints.
5	The accepted requests and GMAP collections are converted into an image collection activity request and forwarded to the Planning and Scheduling function of the MOE.
6	The MOE Planning and Scheduling function uses the collection activity request to generate an overall observatory activity schedule.
7	The MOE Command & Control function converts the observatory activity schedule into a command load. At the time of the uplink opportunity, the Command & Control function sends the command load through the LDCM Ground Network to the observatory, in real time.
7	The Ground Network sends the command sequence to the LDCM observatory during the scheduled command opportunity.
A1	The status of special requests (if any) is passed back to the DPAS.
A2	The DPAS User Portal function makes the status information available to the User Community and Independent CalVal Team member(s) who originally placed the request.

Table 5-1. Daily Activity Scheduling Mission Scenario (LDCM-01)

5.4.2 Collect Wideband Data (LDCM-02)

5.4.2.1 Description

This scenario illustrates the collection of LDCM image data. This scenario begins with the initial collection by the observatory and ends with the ingestion into the DPAS archive. (Note that stored telemetry playback through the wideband link is described in scenario LDCM-05.)

5.4.2.2Assumptions

- All segments are functioning nominally.

5.4.2.3Walkthrough

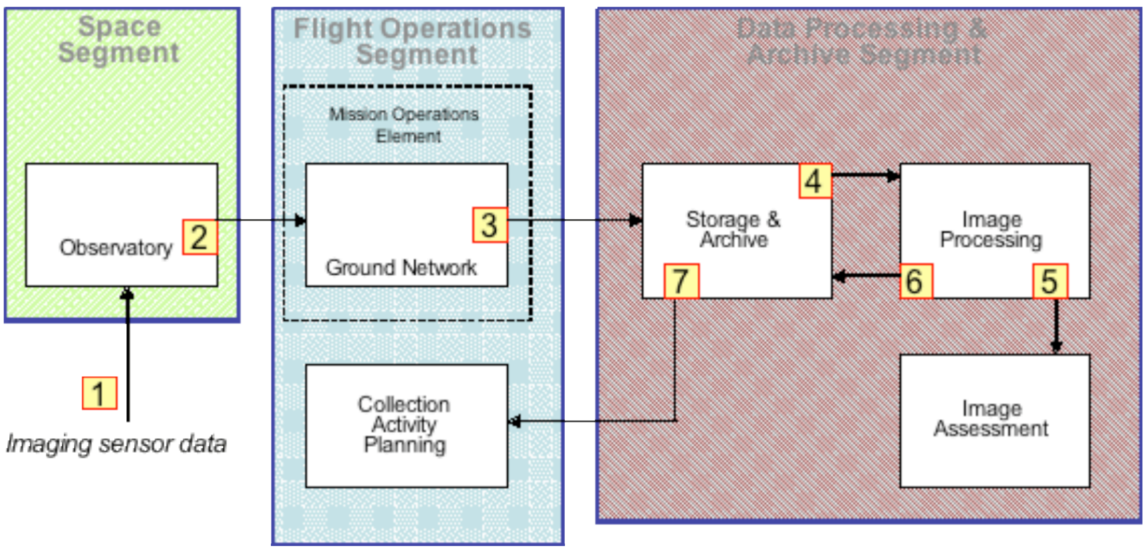

Figure 5-3. Collect Wideband Data (LDCM-02)

Step	Description
1	The Space Segment observatory collects the scheduled image data (refer to scenario LDCM-01)
2	The observatory may optionally store the data on board until the next downlink opportunity. The data are then downlinked to the LDCM Ground Network.
3	A ground station within the LDCM Ground Network receives the data from the Space Segment observatory. The data is then routed to the DPAS.
4	The Storage and Archive function makes the data available to the Image Processing function.
5	The Image Processing function generates scene quality information, metadata and other metrics. The Image Processing function also extracts trend data specified by the Image Assessment function and makes those data available to the Image Assessment function.
6	The Image Processing function makes the archive-formatted data and metadata available to the Storage and Archive function for archival.
7	The Storage & Archive function makes available metadata regarding all data received to the Collection Activity Planning function.

Table 5-2. Collect Image Data Scenario (LDCM-02)

5.4.3 Flight Software Upload Scenario (LDCM-03)

5.4.3.1 Description

This scenario illustrates the routine update of LDCM flight software. The scenario begins with the generation of new flight software and ends with verification that the in-flight software was successfully updated.

5.4.3.2 Assumptions

- All segments are functioning nominally.
- There is some reason to perform a flight software update, and the nature of the update required is well characterized.

5.4.3.3 Walkthrough

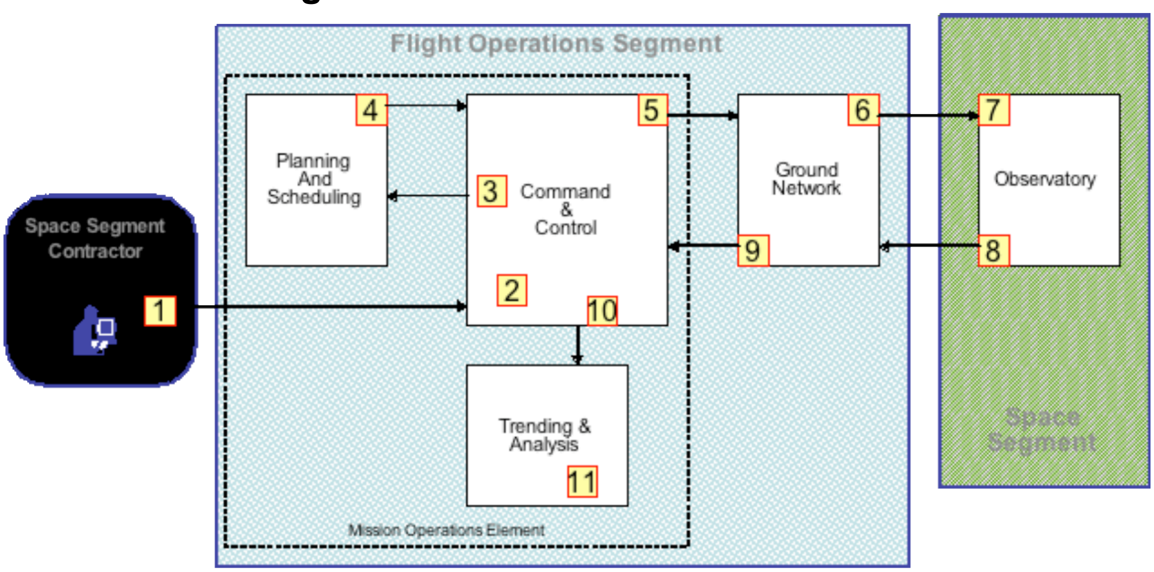

Figure 5-4. Flight Software Update Scenario (LDCM-03)

Step	Description
1	The Prime Mission Contractor generates a new flight software update. This is the actual flight software code, which will be installed in the observatory. The update is sent to the MOE Command and Control function.
2	The Command & Control function generates a command sequence, to apply the flight software update to the observatory.

Step	Description
3	If necessary, the Command & Control function tests the flight software update command sequence using the observatory simulator. This test does not verify the flight software itself, only the command load for applying the software. A flight software update request is forwarded to the Planning and Scheduling function.
4	The Planning & Scheduling incorporates the flight software update into the observatory activity schedule. The observatory schedule is sent back to the Command & Command function.
5,6	The Command & Control function establishes communication with the observatory through the LDCM Ground Network. This communications link is bidirectional and occurs in real time. Through this link, the Command & Control function sends the command load to install the flight software update. Note that it may require multiple contacts with a ground station to uplink an entire flight software update.
7	The observatory receives and executes the command load.
8, 9	The command load would typically include instructions to verify the application of the flight software update, such as checksums, reporting the operating version number and so on. The observatory executes these verification commands and the results are sent back to the Command & Control function through the LDCM Ground Network, in real time.
10	The Command & Control function evaluates the verification data to confirm that the command load was successful. The command load is sent to the Trending and Analysis function for archival.
11	The Trending and Analysis function archives the command load and updated flight software.

Table 5-3. Flight Software Update Scenario (LDCM-03)

5.4.4 User Query Order and Product Distribution Scenario (LDCM-04)

5.4.4.1 Description

This scenario illustrates the routine user query, order and product distribution of a particular LDCM scene(s). The scenario begins with a user initiating a search for data and concludes with delivery of data products to the user.

5.4.4.2 Assumptions

- All segments are functioning nominally.
- The user is requesting a product from archived data.

5.4.4.3 Walkthrough

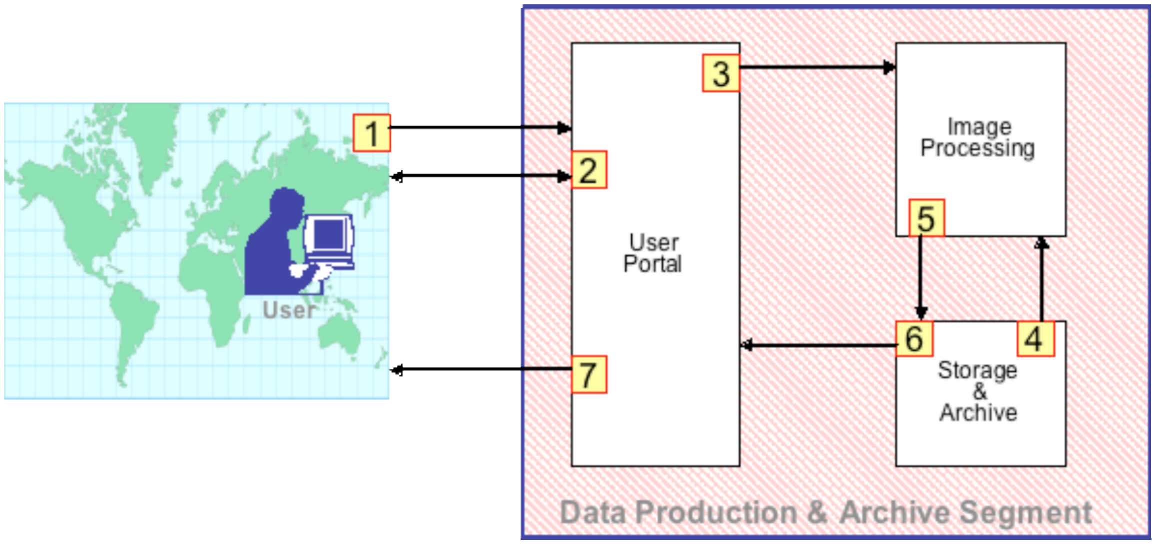

Figure 5-5. User Query Order and Product Distribution Scenario (LDCM-04)

Step	Description
1	The User initiates a search for LDCM data.
2	The DPAS User Portal executes the search and presents results to the User. The User may search several more times, and view browse data and metadata about resulting scenes. The User ultimately chooses scenes for ordering. The User Portal obtains additional information from the User if required (through the same interface) and builds the order(s) required to fulfill the User request.
3	The User Portal generates the processing requests necessary to satisfy the order and passes them to the Image Processing function.
4	The Image Processing function obtains the required data from the Storage and Archive function.
5	The Image Processing function generates the required products. These are made available to the Storage and Archive function.
6	The Storage and Archive function makes the products available to the User Portal function.
7	The User Portal function provides the products back to the User in the format specified. This may be on physical media or via electronic transfer, as specified in the order.

Table 5-4. User Query Order and Product Distribution Scenario (LDCM-04)

5.4.5 Monitor Health & Safety (LDCM-05)

5.4.5.1 Description

This scenario describes the operations performed for both short term and long term monitoring of the spacecraft heath and safety. The scenario begins with the collection of related data on the spacecraft and ends with monitoring / analysis by the FOT operators. (Acting upon any issues found is covered under scenarios LDCM-20 and LDCM-21.)

5.4.5.2 Assumptions

- All segments are functioning nominally.

5.4.5.3 Walkthrough

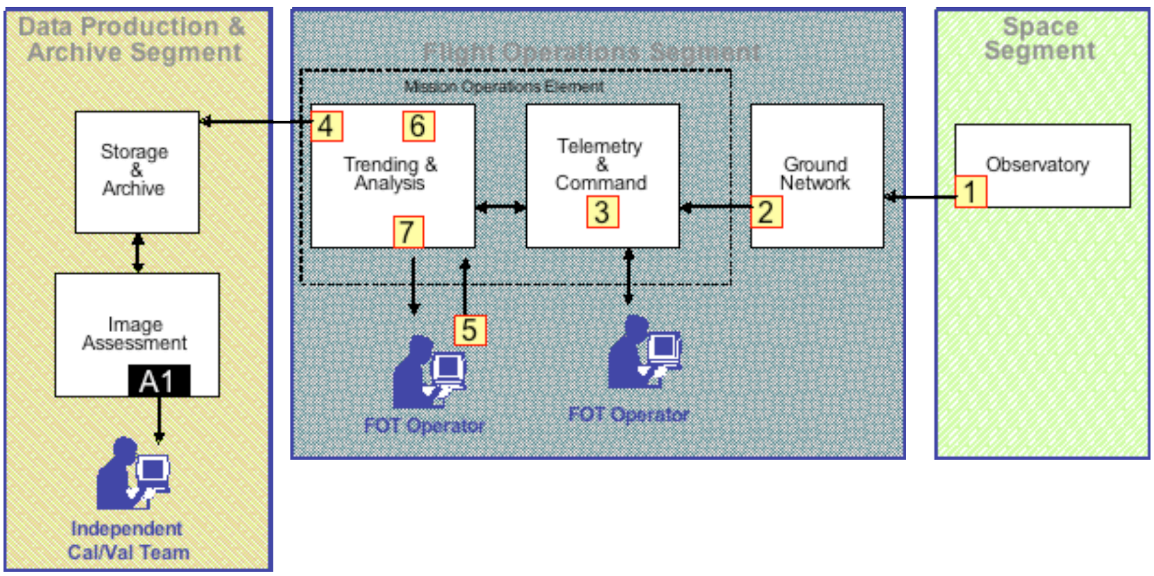

Figure 5-6. Monitor Health & Safety (LDCM-05)

Step	Description
1	The observatory collects telemetry points regarding health & status information of subsystems. These data are stored onboard and later downlinked through the wideband communications stream to the LDCM Ground Network. The real-time telemetry is also downlinked via the S-band stream to the Ground Network.
2	A ground station within the LDCM Ground Network receives the telemetry data. The Ground Network routes this data in real time to the FOS MOE.

Step	Description
3	The FOS Command & Control function automatically monitors all key telemetry points for pre-established limit values. Any out-of-limits value is automatically detected. If a FOT operator is not on staff, the MOE will notify FOT staff so appropriate action can be taken. The FOS Command & Control function presents a real-time summary of all key telemetry points and indicators of any out-of-limits telemetry points. A FOT operator interface allows the operator to investigate certain points during the pass. This interaction with a FOT operator may be optional (TBD6) if the FOS is not staffed 24/7.
4	Following each telemetry pass contact, the data are saved into an archive. This archive contains all telemetry data acquired since launch. The Trending and Analysis function makes a copy of the telemetry data available to the Storage & Archive function within the DPAS for use by the Independent Cal/Val Team.
The following thread represents the long-term monitoring capability.	
5	A FOT operator (engineer or other FOS team member) interfaces to the FOS Trending and Analysis function, and initiates an analysis session. The operator chooses what data to evaluate, such as battery temperature data or any other data contained in the telemetry archive
6	The Trending and Analysis function retrieves all relevant data from the telemetry archive. Processing is performed as required / specified by the operator conducting the analysis.
7	The Trending and Analysis function presents the results to the operator. The operator may perform a number of steps, including starting new analysis, exporting data for further analysis, updating telemetry point limits and so on.
A1	Independent Cal/Val Team members interface to the Image Assessment function to access observatory state of health data for the long term calibration and performance monitoring of the instrument(s) and any calibration components/devices.

Table 5-5. Monitor Health & Safety (LDCM-05)

5.4.6 Priority Scene Acquisition & Delivery (LDCM-06)

5.4.6.1 Description

This scenario describes the operations performed when priority data acquisition requests are received. This scenario begins with the initiation of a request by a User and ends with delivery of data products to the User.

5.4.6.2 Assumptions

- All segments are functioning nominally.
- The priority scene request is approved by the Data Collection Planner as falling within the policy guidelines for such requests.

5.4.6.3 Walkthrough

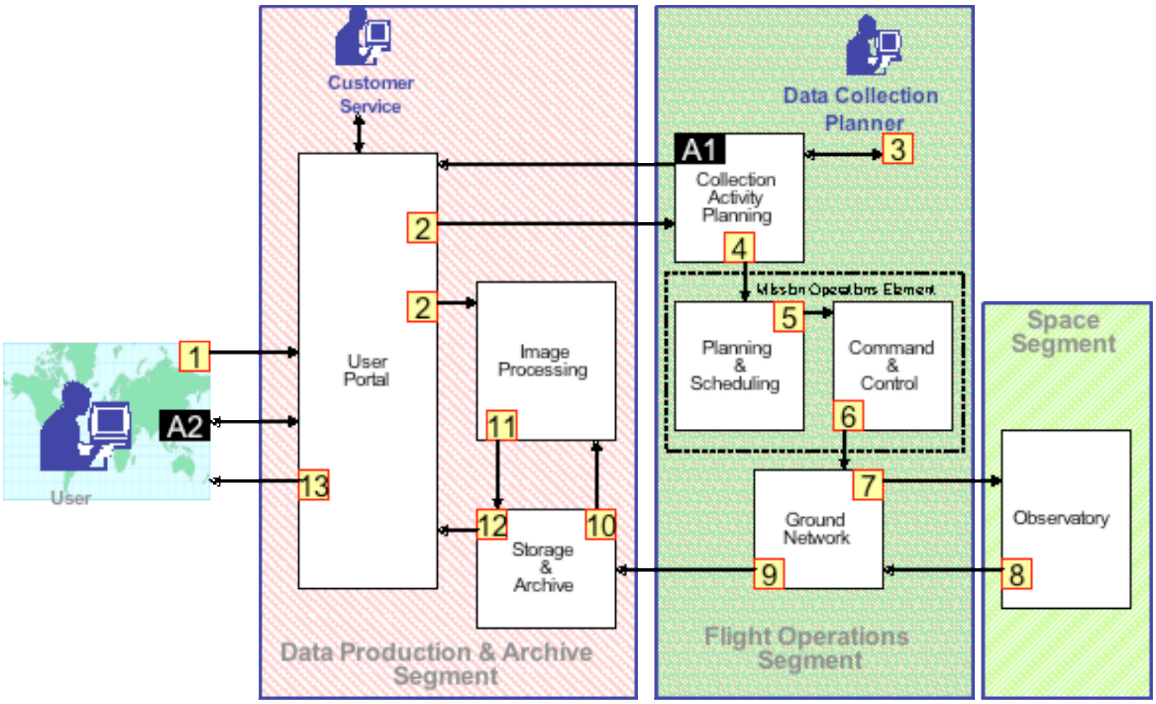

Figure 5-7. Priority Scene Acquisition & Delivery (LDCM-06)

Step	Description
1	A User identifies a need for priority data acquisition & delivery. The User submits this request to the DPAS through the User Portal function. (The user may also contact a Customer Service agent on the telephone, who in turn enters the request into the User Portal on their behalf.) There is an account-level control over who may submit Priority data collection requests.
2	The User Portal sends the acquisition request to the Collection Activity Planning function within the FOS.
3	The Data Collection Planner interacts with the Collection Activity Planning function. The DCP translates the acquisition request into a set of specific acquisitions necessary to complete the request.
4	The Collection Activity Planning function develops a collection activity request, which incorporates the priority request, along with other regularly scheduled acquisitions, adjusted to accommodate the Priority request if necessary. This request is sent to the Planning & Scheduling function.

Step	Description
5	The Planning & Scheduling function develops or revises the observatory activity schedule. The Planning & Scheduling function schedules either a Ground Network contact. The observatory activity schedule and resources are passed to the Command & Control function.
6,7	The Command & Control function translates the activity schedule into a command load. At the scheduled time, the Ground Network establishes contact with the observatory. In real time, the Command & Control function sends the command load to the observatory through the Ground Network.
8	The observatory acquires the Priority image data. The Priority scenes are flagged and handled differently from other image data. At the next scheduled Ground Network contact, the observatory downlinks all Priority scenes first, instead of sending down the oldest data stored on the observatory.
9	The priority scenes are sent to the DPAS Storage and Archive function from the Ground Network station.
10	The Storage and Archive function makes the priority data available to the Image Processing function immediately upon receipt.
11	The Image Processing function generates the requested data products and makes them available to the Storage and Archive function for temporary storage.
12, 13	The User Portal sends the products to the User. In the priority scenario, it is anticipated that users will normally order electronic delivery.
	This alternate thread illustrates a status capability
A1	The Planning & Scheduling function notifies the User Portal of the particular acquisitions identified to satisfy this request. The Planning & Scheduling function updates this information if there are any changes.
A2	At any time the User may query the User Portal to inquire about the status of the acquisition request.

Table 5-6. Priority Scene Acquisition & Delivery (LDCM-06)

5.4.6.4 Scenario Timeline

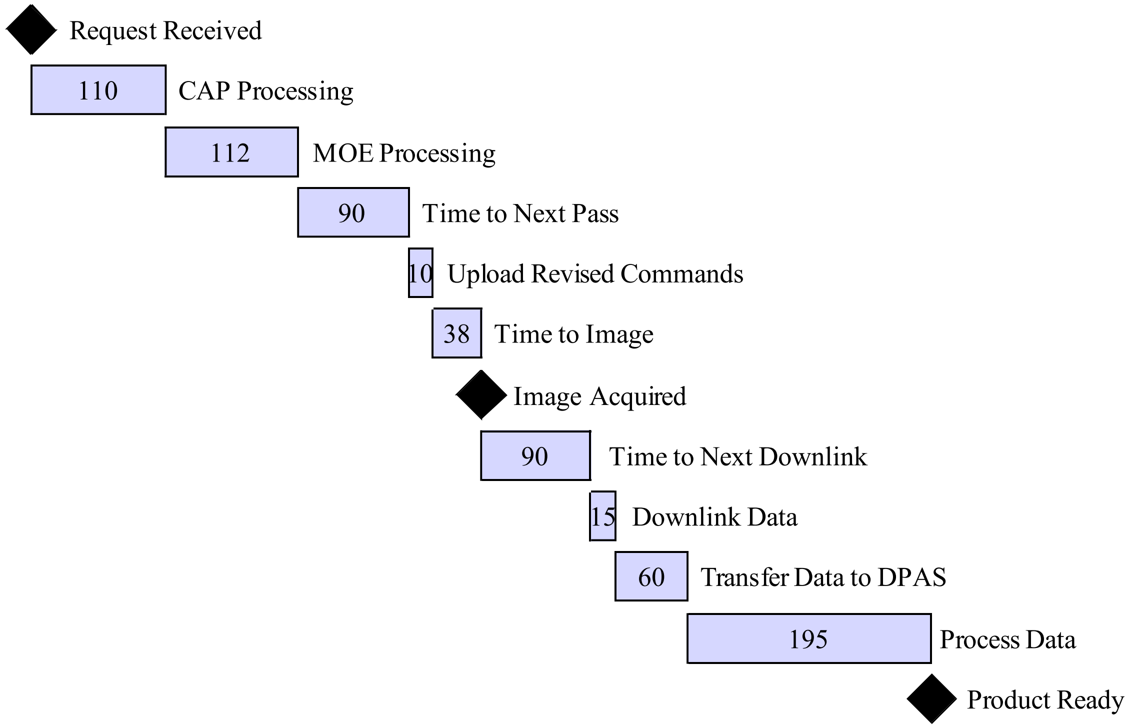

Figure 8. Priority Scene Acquisition & Delivery Timeline

Figure 8 presents the timeline established to meet the worst case scenario for scheduling a priority acquisition and processing products from a priority acquisition. The numbers in each block represent the minutes allocated to that step to meet the timeline. The table below ties the steps on the timeline to the scenario steps from section 5.4.6.3 and provides additional notes.

Timeline Step	Scenario Steps	Notes
Request Received	1	
CAP Processing	2,3,4	
MOE Processing	5,6	
Time to Next Pass	6	The worst case is that a pass just completed and we must wait until the start of the next command uplink opportunity on the following orbit.
Upload Revised Commands	7	
Time to Image	8	The worst case is for a scene at the southern tip of South America – Antarctic scenes would require more time.
Image Acquired	8	

Timeline Step	Scenario Steps	Notes
Time to Next Downlink	8	The worst case is for a scene acquired immediately following an LGN contact.
Downlink Data	8	
Transfer Data to DPAS	9	The worst case is to assume data was downlinked to a station other than EROS, so network transfer must take place.
Process Data	10,11,12	
Product Ready	13	

Table 5-7. Priority Scene Acquisition & Delivery Timeline Details

5.4.7 Maintain Orbit (LDCM-07)

5.4.7.1Description

This scenario describes the processes related to station keeping for the LDCM spacecraft. The scenario begins with measurements of the spacecraft position and ends with confirmation that maneuvers were completed successfully.

5.4.7.2Assumptions

- All segments are functioning nominally.

5.4.7.3Walkthrough

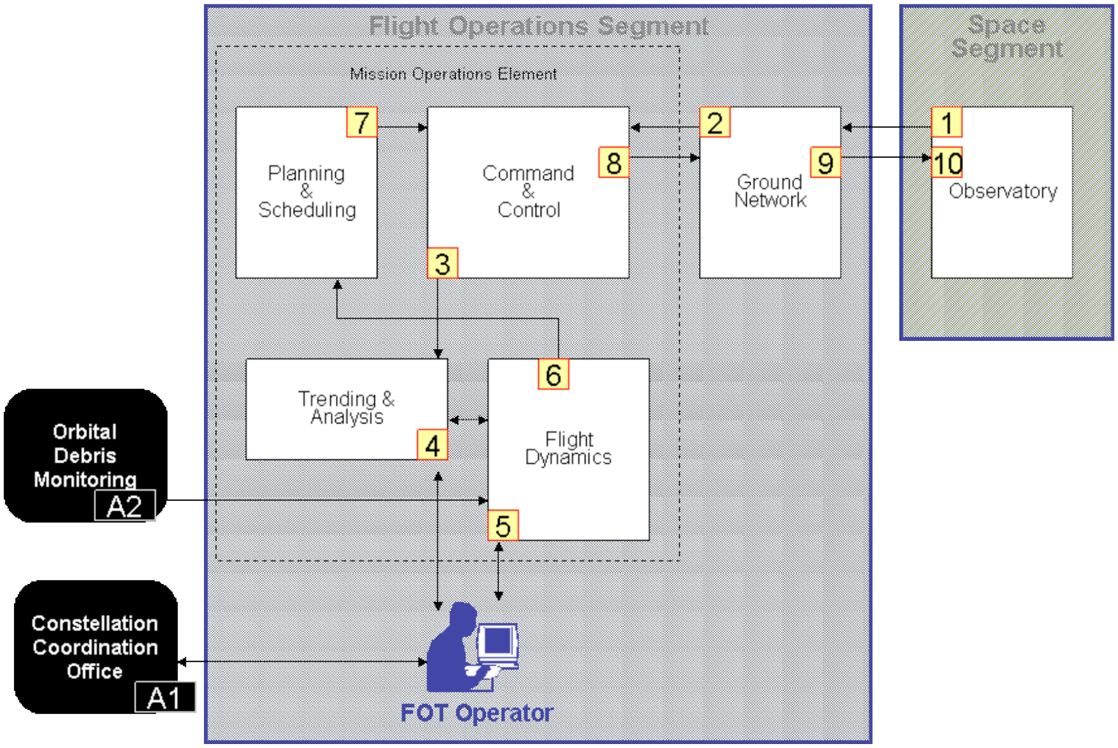

Figure 5-9. Maintain Orbit (LDCM-07)

Step	Description
	This scenario begins with measurements relevant to the determination of the spacecraft precision ephemeris. These measurements occur asynchronously and are represented as parallel flows for the purpose of this scenario.
1	The observatory performs measurements relevant to orbit determination. These measurements are included as part of the standard telemetry stream during contacts with stations in the ground network.
2	The Ground Network stations forward the telemetry data to the Command & Control function, in real time.
3	The Command & Control function passes all the telemetry data to the Trending and Analysis function for archival after the ground network contact is completed. These data include the observatory measurements.
A1	The GSFC Constellation Coordination Office coordinates with the FOT Operators (TBD8). This coordination is to ensure adequate operational safety in the group of satellites flying in the same orbital plane as LDCM.

Step	Description
A2	The Air Force Cheyenne Mountain staff sends orbital debris monitoring alerts to the Flight Dynamics function. These are position data for orbital debris, which may impinge upon a certain radius of the LDCM spacecraft.
4	The FOT operator evaluates telemetry and makes a determination as to whether a maneuver is required to maintain orbit and mission safety.
5	The FOT Operator uses the Flight Dynamics function to derive the details of the orbital maneuver(s) required.
6	A maneuver request is sent to the Planning and Scheduling function.
	Note that the planning of maneuvers is done well in advance of the maneuver. Steps 4, 5, 6 and 7 are all expected to occur after a significant amount of coordination on the part of FOT staff. Steps 4, 5, 6 and 7 may be completed days or even weeks in advance of the actual maneuver.
7	The Planning and Scheduling function allocates resources for executing the maneuver. This includes scheduling the Ground Network contact for the commanding, and potentially identifying a period of time during which no mission data acquisitions will be performed, for input to the scheduling process. The maneuver is then incorporated into the observatory activity schedule.
8, 9	The Command and Control function coverts the observatory activity schedule into a command load. At the time of the contact, the Command & Control function establishes contact with the observatory through the Ground Network. This communication is accomplished in real time. The command load is sent to the observatory through the Ground Network.
10	The observatory executes the commanded maneuver sequence.
	Note that this is an iterative process. Following the maneuver, measurements are taken to ensure that the observatory is in the intended orbit. Therefore the system proceeds to steps 1 and 2 of this scenario, and repeats.

Table 5-8. Maintain Orbit (LDCM-07)

5.4.8 IC Scheduling and Delivery (LDCM-08)

5.4.8.1 Description

This scenario illustrates the primary interactions between LDCM and the International Cooperators (ICs). This scenario begins with the IC request for image collection and ends with the delivery of data to the IC.

5.4.8.2 Assumptions

- All segments are functioning nominally.

5.4.8.3 Walkthrough

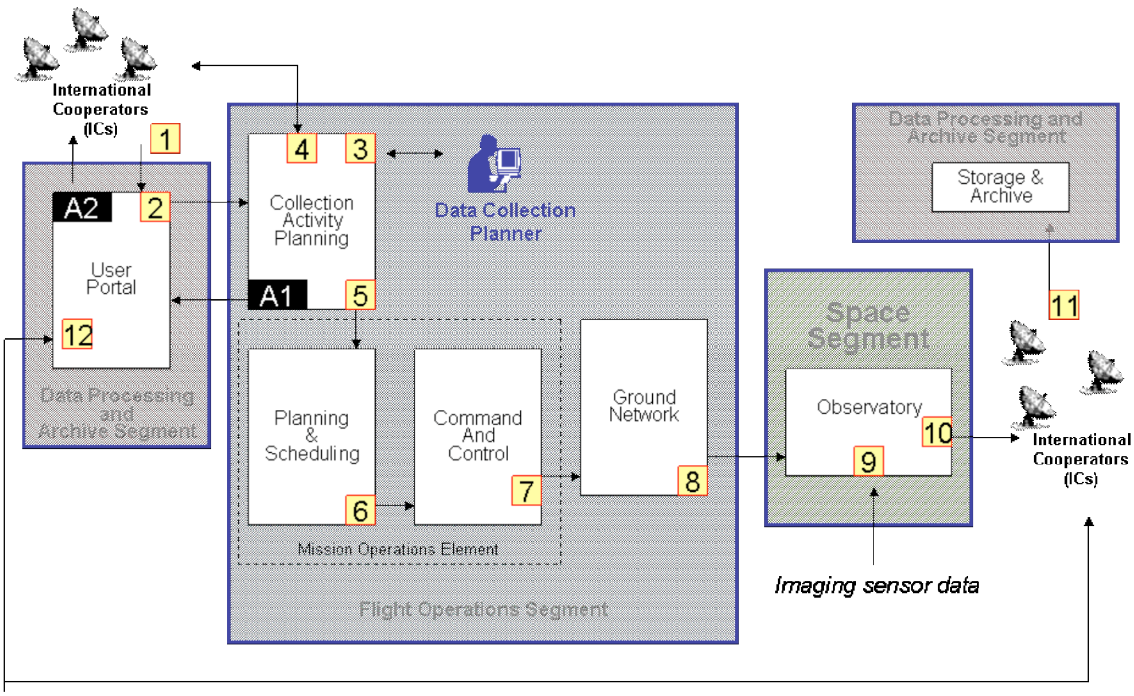

Figure 5-10. IC Scheduling and Delivery (LDCM-08)

Step	Description
1	An IC generates and submits an image collection request that is not in the daily activity or collection schedule. The IC interfaces with the DPAS User Portal function to submit request.
2	The DPAS forwards the collection request to the FOS for consideration.
3	As part of the Collection Activity Planning function, all IC requests are evaluated by the Data Collection Planner (DCP) for acceptance or rejection, guided by established policy. The accepted requests and GMAP are combined based on predicted cloud cover probabilities, existing archive quality and extent, and engineering constraints to form the collection activity request.
4	The Collection Activity Planning function coordinates with the IC for the availability and scheduling of IC ground stations resources to receive LDCM data. Each IC is coordinated with and scheduled on an individual basis.
5	The collection activity request is forwarded to the MOE.

Step	Description
6	The collection activity request is combined with other observatory activities being managed by the MOE Planning and Scheduling functions. MOE Planning and Scheduling functions allocate resources, perform any needed activity de-confliction, and generate the observatory activity schedule, which is forwarded to the MOE Command and Control function.
7	The Command and Control function uses the activity schedule to generate a command sequence, and forwards this to the LDCM Ground Network.
8	The Ground Network sends the command sequence to the LDCM observatory during the scheduled command opportunity.
9	The observatory collects the scheduled image data. The image data is stored on board the observatory for future downlink to an LDCM ground station.
10	In real-time, the observatory transmits the image data as it is collected to the IC ground station.
11	The IC ground station notifies the DPAS Storage and Archive function of the receipt of the wideband data and provides related information associated with the collection.
12	If additional calibration data is needed, the ICs access it through the DPAS User Portal function.
A1	The status of IC requests (if any) is passed back to the DPAS.
A2	The DPAS User Portal function makes the status information available to the User Community and Independent CalVal Team member(s) who originally placed the request.

Table 5-9. IC Scheduling and Delivery (LDCM-08)

5.4.9 Communications with TDRSS (LDCM-09)

5.4.9.1 Description

This scenario describes the interactions between LDCM and TDRSS. This scenario begins with the scheduling of TDRSS resources and ends with the receipt of S-band telemetry stream.

5.4.9.2 Assumptions

- All segments are functioning nominally.

5.4.9.3Walkthrough

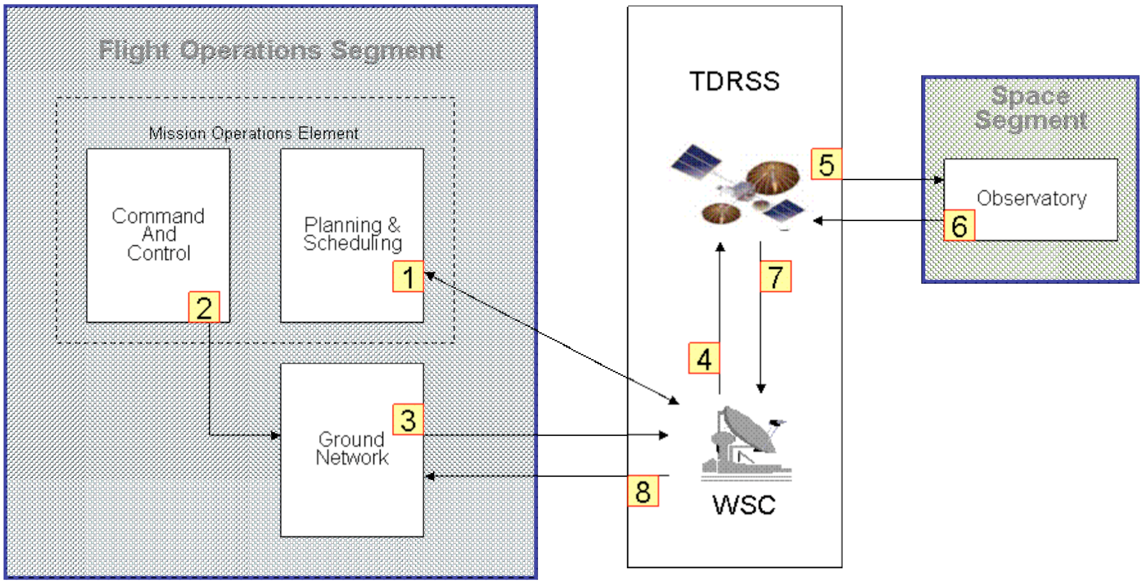

Figure 5-11. Communications with TDRSS (LDCM-09)

Step	Description
1	The FOS MOE Planning and Scheduling function coordinates with the TDRSS White Sands Complex (WSC) for the availability and scheduling of TDRSS resources to communicate with LDCM.
2	The MOE Command and Control function generates a command sequence, and forwards this to the LDCM Ground Network.
3	The Ground Network sends the command sequence to the TDRSS WSC ground station.
4, 5	The WSC ground station transmits the S-band communications stream to a TDRSS satellite. The TDRSS satellite tracks the LDCM observatory and relays to it the S-band communication.
6, 7	The observatory generates telemetry data and transmits an S-band communications stream to a TDRSS satellite. The TDRSS satellite relays the S-band communications stream to the TDRSS WSC ground station.
8	The WSC ground station forwards the received S-band telemetry data to the LDCM ground network.
At this point this scenario is over. In practice, several scenarios could be initiated at this point, including LDCM-03, LDCM-05, LDCM-07, and LDCM-20.	

Table 5-10. Communications with TDRSS (LDCM-09)

5.4.10 Safehold/Autonomous Failsafe Occurrence and Recovery Mission Scenario (LDCM-20)

5.4.10.1 Description

This scenario illustrates the non-nominal activity associated with an anomaly identified onboard the observatory and the fail-safe process the observatory will complete without ground interaction. The scenario begins with a fault condition and ends with notification of the FOS that the observatory is in safe-hold mode.

5.4.10.2 Assumptions

- All segments are functioning nominally.
- The observatory flight software has been developed such that continuous health and status data is recorded, analyzed and logged on board, allowing for detection of fault situations.
- A continuous over-temperature condition occurs that causes a fault situation (not intermittent).
- Observatory enters safehold mode and cannot change modes without ground commanding.
- The observatory successfully enters safe-hold mode.

5.4.10.3 Walkthrough

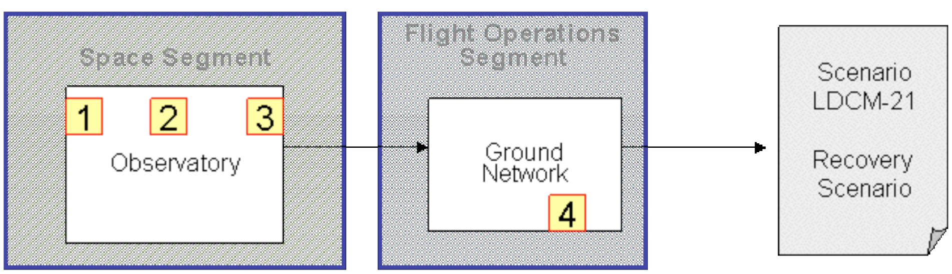

Figure 5-12. Safehold/Autonomous Failsafe Occurrence and Recovery Mission (LDCM-20)

Step	Description
1	An over-temperature condition occurs. The observatory detects over-temperature condition during routine internal health and status monitoring. The observatory verifies the condition and continues data logging.
2	The observatory initiates the safe-hold protocol by shutting down all non-essential hardware and processes (but continuing to log data) and continues until successfully completed. After completion of safing, data logging continues.

Step	Description
3	The observatory downlinks S-band data to a ground station within the FOS Ground Network at the next opportunity.
4	The Ground Network routes the data to appropriate FOS teams for analysis and archiving. The routing of telemetry data is identical to that shown in scenario LDCM-06.
At this point this scenario is over. In practice, the system immediately initiates scenario LDCM-21 upon detection of the safe-hold condition within the FOS.	

Table 5-11. Safehold/Autonomous Failsafe Occurrence and Recovery Mission Scenario (LDCM-20)

5.4.11 Non-Autonomous Anomaly Correction (LDCM-21)

5.4.11.1 Description

This scenario describes the process of anomaly resolution. The scenario begins with the establishment of an Anomaly Resolution Team and ends with the determination of the appropriate procedures to correct the anomaly.

5.4.11.2 Assumptions

- An anomaly has occurred and has been detected by FOT

5.4.11.3 Walkthrough

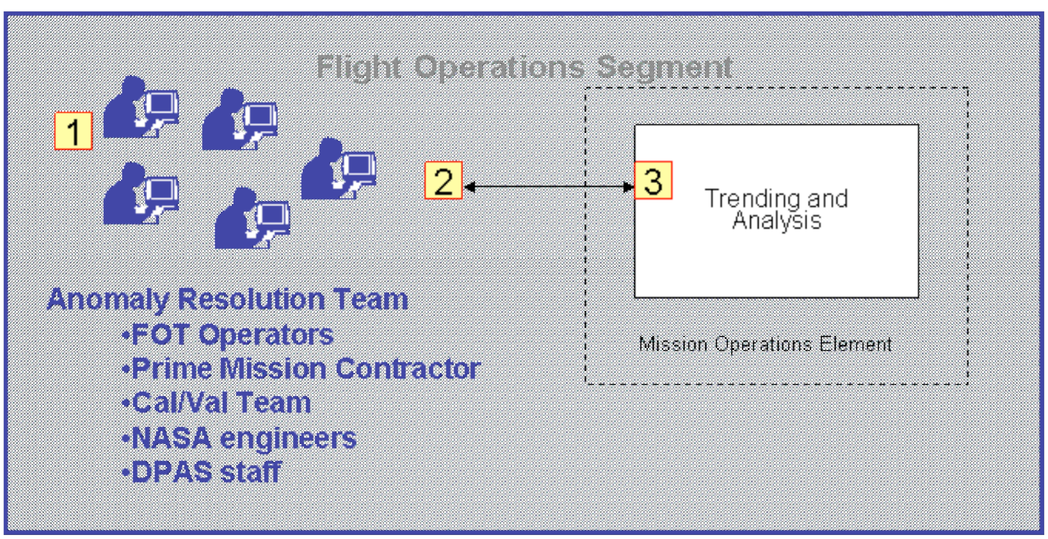

Figure 5-13. Non-Autonomous Anomaly Correction (LDCM-21)

Step	Description

Step	Description
1	An Anomaly Resolution Team (ART) is formed. The ART may be comprised of the following representatives, depending on the type of anomaly: FOT operators, Prime Mission Contractor observatory sustaining engineering support, NASA discipline engineering support, DPAS support, and the Independent Cal/Val team. If the anomaly occurs prior to on-orbit acceptance, the ART is led by PMC with NASA oversight. If the anomaly occurs following on-orbit acceptance, the ART is led by the USGS.
2	The ART interfaces to the Trending and Analysis functions to study and analyzes observatory engineering and state of health data.
3	The ART develops and evaluates possible anomaly resolution options and evaluates them using the capabilities within the Trending and Analysis functions. A spacecraft anomaly report is generated and becomes the official document to track and close the incident Steps 2 and 3 may be performed iteratively until the anomaly resolution plan and procedures are determined.
At this point, this scenario ends. Depending on the type of anomaly and resolution, a number of different events or scenarios could be initiated at this point including a flight software update (LDCM-03), activation of redundant flight systems, a modification in image data collection or processing, or others.	

Table 5-12. Non-Autonomous Anomaly Correction (LDCM-21)

5.4.12 Retransmission (LDCM-22)

5.4.12.1 Description

This scenario describes two possible levels of LDCM data retransmission which the LDCM system will provide.

5.4.12.2 Assumptions

- LDCM data was acquired as normal, transferred to the DPAS, and the resulting data was judged invalid.

5.4.12.3 Walkthrough

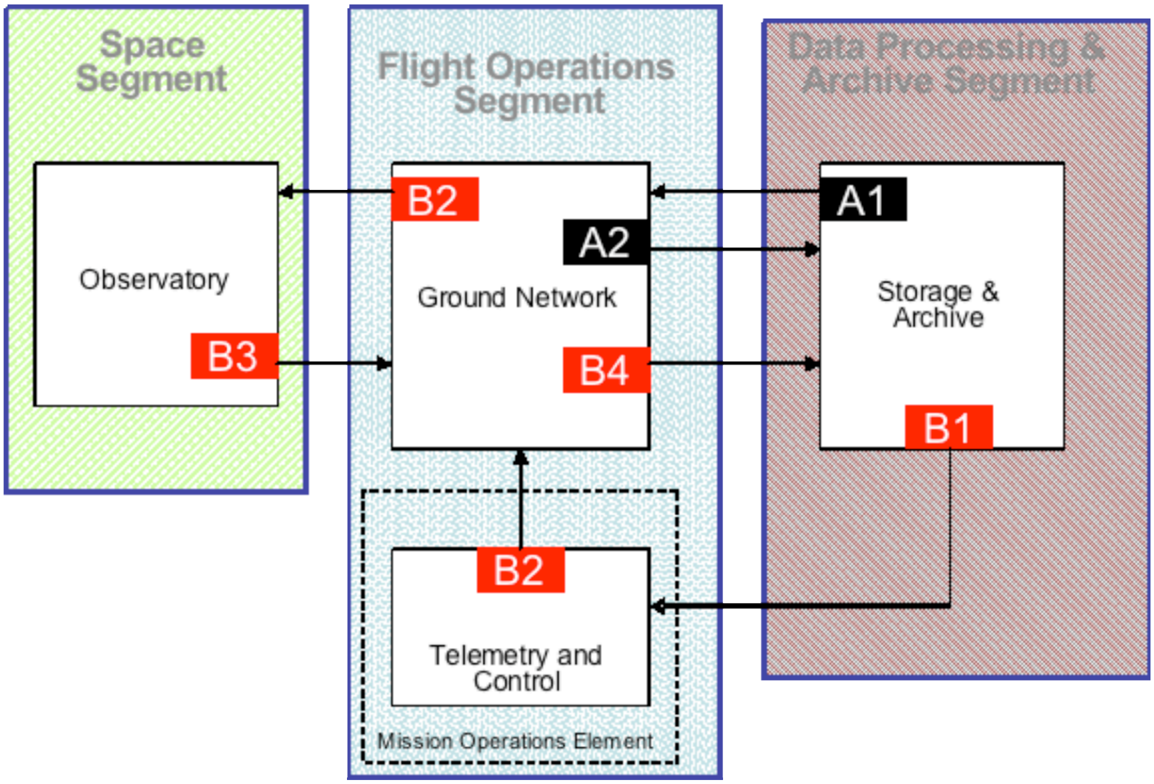

Figure 5-14. Retransmission (LDCM-22)

Step	Description
A1	The Storage & Archive function requests that the Ground Network re-transfer LDCM data to the Storage & Archive function. This request can only be placed within the fixed period of time for which the Ground Network nodes cache data for this purpose.
A2	The Ground Network makes the LDCM data available to the Storage & Archive function.
B1	The Storage & Archive function initiates a request for the retransmission of data held on the LDCM Observatory. This request can only be placed for data originally flagged to hold for retransmission, and only while the MOE Command and Control function has not instructed the Observatory to delete the data.
B2	The Command and Control function transmits a command for retransmission from the observatory. This could be done either during the normal once per day commanding, or as a priority retransmission, as the mode of the data warrants.
B3	The Observatory sends the requested data back down to the Ground Network as requested in the command load.
B4	The Ground Network makes the LDCM data available to the Storage & Archive function.

Table 5-13. Retransmission (LDCM-22)

5.4.13 Backup Flight Operations

As discussed in section 3.2, the LDCM has a backup flight operations center capability. The Mission Operations Manager can transfer operations responsibility to the backup location at any time. The switchover may be initiated from the backup mission operations center, without interaction with the primary mission operations center. No scenario is shown for this because the details of activating the backup mission operations center are design details. All nominal and non-nominal operations can be executed from the backup location.

To ensure that the backup capability is ready, operations will be moved to the backup location on a routine periodic basis.

5.5 Decommissioning

At the end of the mission, the LDCM will undergo decommissioning. The decommissioning of the LDCM observatory will comply with the NASA Policy for Limiting Orbital Debris Generation, NPD 8710.3.